BBC

THE PLANETS

The Open University | 50 YEARS

ZOOM IN

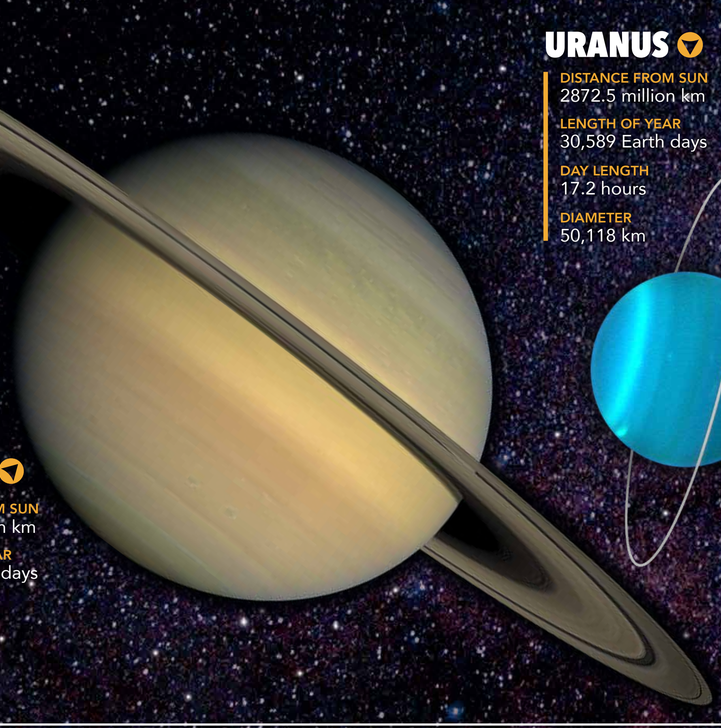
JUPITER

DISTANCE FROM SUN
778.6 million km

LENGTH OF YEAR
4331 Earth days

DAY LENGTH
9.9 hours

DIAMETER
142,984 km



SATURN

DISTANCE FROM SUN
1433.5 million km

LENGTH OF YEAR
10,747 Earth days

DAY LENGTH
10.7 hours

DIAMETER
120,536 km

URANUS

DISTANCE FROM SUN
2872.5 million km

LENGTH OF YEAR
30,589 Earth days

DAY LENGTH
17.2 hours

DIAMETER
50,118 km

NEPTUNE

DISTANCE FROM SUN
4495.1 million km

LENGTH OF YEAR
59,800 Earth days

DAY LENGTH
16.1 hours

DIAMETER
49,528 km

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MERCURY

The smallest and closest planet to the Sun, its lack of atmosphere makes Mercury hot by day and cold by night.

Mercury rotates exactly three times for every two orbits. Bizarrely, the result of this is that its day lasts twice as long as its year. It contains a large iron core, which generates a magnetic field. The surface is rocky and is made mostly of volcanic lava flows pockmarked by impact craters.

DISTANCE FROM SUN
57.9 million km

LENGTH OF YEAR
88.0 Earth days

ROTATION PERIOD
1407.6 hours

DAY LENGTH
4222.6 hours

DIAMETER
4879 km

VENUS

An almost Earth-sized planet with a dense and cloudy atmosphere that hides the surface from view.

To map the surface of Venus from orbit we have to use radar to penetrate the clouds. Venus spins very slowly backwards, hence the negative sign in its rotation period, although its clouds rotate 60 times faster. Its surface is mostly lava flows, which are much younger than those on Mercury.

DISTANCE FROM SUN
108.2 million km

LENGTH OF YEAR
224.7 Earth days

ROTATION PERIOD
-5832.5 hours

DAY LENGTH
2802.0 hours

DIAMETER
12,104 km

EARTH

The only planet to have abundant liquid water today and an atmosphere that we can breathe.

Earth's core generates a magnetic field. Its surface is divided into plates that grow by spreading at mid-ocean ridges and slide below the edges of continents, which causes many earthquakes and volcanic eruptions. Earth is the only known home to life, which in turn has hugely changed the planet.

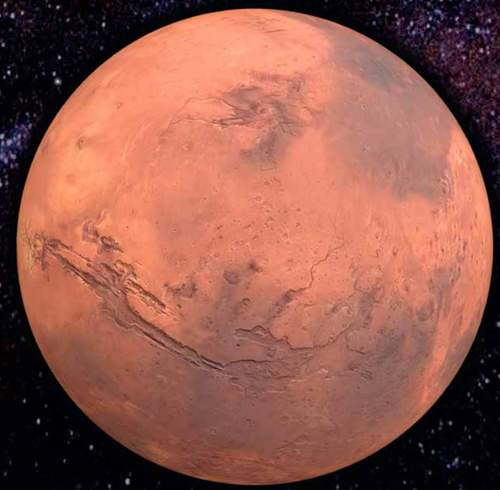
DISTANCE FROM SUN
149.6 million km

LENGTH OF YEAR
365.2 Earth days

ROTATION PERIOD
23.9 hours

DAY LENGTH
24.0 hours

DIAMETER
12,756 km



MARS

A world that had liquid water long ago, but has changed to a cold, dry climate.

Mars has canyons, valleys, giant volcanoes and dusty plains. The hunt is on to find out whether there was any life there in the distant past when conditions were more suitable, and even whether any microbes still live there today. Mars lost its ancient magnetic field and its early atmosphere.

DISTANCE FROM SUN
227.9 million km

LENGTH OF YEAR
687.0 Earth days

ROTATION PERIOD
24.6 hours

DAY LENGTH
24.7 hours

DIAMETER
6792 km

THE PLANETS

Discover more about our Solar System's planets and moons

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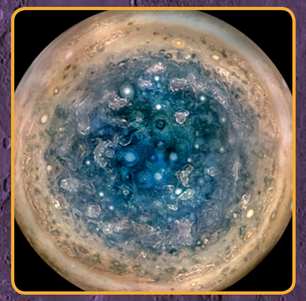
JUPITER

Jupiter is the largest planet in the Solar System, with a mass about two and a half times that of the other seven planets combined. Jupiter has played a key role in the evolution of the Solar System, sweeping up debris and affecting the orbits of asteroids, comets and other planets.



Jupiter swept up much of the mass in the disc around it as the primordial Solar System formed, and it is thought to contain broadly the same mix of elements as the early Sun. Despite its great mass (almost 318 times that of the Earth), Jupiter is still small compared to the Sun, at about one thousandth of its mass. Jupiter did not grow large enough to begin nuclear fusion within its interior and become a star itself, but it does produce its own interior heat, at a rate which is roughly the same as the average power that it receives from the Sun. This heat is thought to come from gravitational energy from Jupiter's formation and from a gradual contraction that continues to this day. Jupiter is still shrinking, but only one or two centimetres per year in diameter is needed to account for the heat observed!

As a result of its rapid rotation, with a day of less than ten hours, Jupiter is noticeably flattened with an equatorial diameter that is more than 6% longer than its polar diameter. This can be seen through even a small telescope, where Jupiter's disc appears oblate rather than circular.

Jupiter probably has a central core of rock and ice, but this makes up only around 10% of the entire planet's mass (in the region of 10–50 Earth masses). Most of the planet is primarily hydrogen and helium. These behave like familiar gases only over a relatively shallow (1,000 km) shell below the clouds. As the pressure increases, hydrogen behaves more like a liquid. At about 4 million Earth atmospheres of pressure, hydrogen takes a liquid, metallic form, which is a superconductor of electricity. This pressure is exceeded over about 80% of the total radius of Jupiter and much of the deep interior of the planet is thought to be metallic hydrogen.

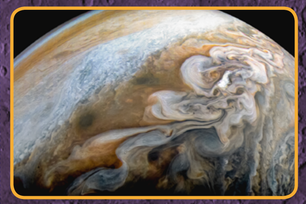
Jupiter generates a powerful magnetic field where hydrogen begins to act as an electrical conductor. This interacts with the solar wind and produces spectacular aurorae at high latitudes. Charged particles, trapped in Jupiter's huge magnetic field, form radiation belts that can be a hazard to spacecraft.

The atmospheric circulation of Jupiter is dominated by alternating east–west jets which are linked to the banded appearance of the planet. The 'zones' are regions of high, white clouds, where the atmosphere is upwelling, and the 'belts' are darker regions of subsidence where lower cloud decks are seen. Wind speeds peak at the boundaries between zones and belts and can reach more than 600 km/h. Embedded within this pattern are a variety of white and coloured 'spots' which are long-lived storms that can persist for many years.

The banded structure of Jupiter's clouds breaks down near the poles, where a beautiful array of smaller vortices has been revealed by the NASA Juno spacecraft.

Jupiter's swirling clouds are what gives the planet its beautiful appearance. The white regions are higher clouds of ammonia crystals and the darker ones are deeper, water–ice clouds. The lower clouds are coloured by impurities, such as phosphorous, sulphur and hydrocarbons, brought up from the deeper atmosphere. These react with ultraviolet sunlight to produce the colours seen.

Jupiter has many moons: 79 have been discovered to date, and the four largest – Io, Europa, Ganymede and Callisto – are easily visible from Earth using binoculars.

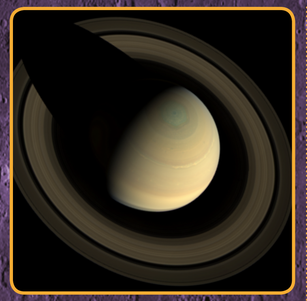


Did You Know?

Jupiter's 'Great Red Spot' is a storm that has raged since at least the nineteenth century and was probably seen by Robert Hooke in 1664. It is a high-pressure anticyclone which dredges up coloured compounds from beneath. It is shrinking now but is still larger than the Earth.

SATURN

Saturn is famous for its beautiful rings, easily seen through a small telescope from Earth and made almost entirely of water ice , with only a little rock and dust. The diameter of the main rings is about 280,000 km, but they are incredibly thin, averaging only 20 m thick.



The interior of Saturn is similar to that of Jupiter, with a rock and ice core (similar in size, but only 9–20 Earth masses), and the planet is predominantly composed of hydrogen and helium. Hydrogen enters its metallic phase at greater depths here than on Jupiter because Saturn is less massive (about 95 Earth masses in total). Consequently the required pressure only occurs within a region surrounding the core out to about half the planet's total radius. The majority of Saturn's volume is taken up by liquid hydrogen and helium, with an outer shell of around 1,000 km that is gaseous.

Like Jupiter, Saturn has an interior heat source. While being less powerful than that of Jupiter, Saturn's interior heat source provides two and a half times more power than Saturn receives on average from the Sun. Unlike Jupiter, this heat is hard to account for solely by gravitational compression and it seems that more is generated by elements heavier than hydrogen (from helium upwards) falling preferentially towards the core, thus releasing gravitational potential energy.

Saturn has a blander appearance than that of Jupiter, with less contrast in colour between low and high clouds. As on Jupiter, high clouds are generally ammonia ice crystals and below these lie layers of water-ice clouds, with solutions of ammonia and regions of ammonium hydrosulphide ice also possible. Occasional storms are seen as bright patches of high, white ammonia cloud. The ability to see contrasts, and features that can be used to track winds, requires either spacecraft observations or powerful telescopes, such as the Hubble Space Telescope.

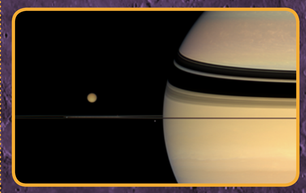
Winds on Saturn are organised into alternating jets, as on Jupiter, but with a broader and faster equatorial jet, where speeds can reach 1,800 km/h, second only in the Solar System to winds seen on Neptune.

Periodically, storms appear on Saturn as bright, white cloud tops, like high thunderstorm clouds on Earth. These are relatively short-lived compared to Jovian spots.

A series of clouds covering a large part of a hemisphere, sometimes known as the 'Great White Spot', seems to appear every Saturnian year (just under 30 Earth years) for a few months.

A more permanent feature of Saturn's atmosphere is the hexagonal pattern centred on the North Pole, seen in the image on the left. The hexagon was discovered during the Voyager spacecraft flyby in 1981 and has been watched by the Cassini spacecraft in orbit from 2004–2017. Each side of the hexagon is longer than the diameter of the Earth. The hexagon rotates once every 10.7 hours, at exactly the same rate as the interior of Saturn, measured by the rotation of its magnetic field. The hexagon is a standing-wave pattern in a high-latitude jetstream, with wind speeds of 320 km/h. Why it is so stable, and why a similar feature is not seen in the southern hemisphere, is a mystery.

Saturn has 62 known moons as of 2019, but this does not include hundreds of small moonlets in Saturn's rings, each smaller than 500 m. Titan is the largest and most massive moon, and at 5,139 km diameter is the second largest moon in the Solar System (only Jupiter's moon Ganymede is larger) and is larger than the planet Mercury. Titan has a thick atmosphere of mainly nitrogen, with a surface pressure 1.5 times that on Earth and freezing temperatures of about -180 °C.

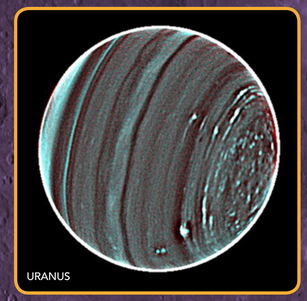


Did You Know?

Saturn is best known for its visually striking rings, but all four giant planets have ring systems. Saturn might not always have had such prominent rings. They are likely to be the icy debris of a moon that was broken up as its orbit approached Saturn.

URANUS & NEPTUNE

Uranus and Neptune are sometimes called the 'ice giants' because their interiors are thought to contain more ice and less gas than the larger gas giants. They were unknown until after the invention of the telescope, Uranus being discovered in 1781 and Neptune in 1846.



Only one spacecraft, Voyager 2, has flown past these two planets, and little detail could be seen on them from Earth until the advent of very modern telescope imaging techniques. The view of Uranus shown above was captured in near-infrared light by the Keck Telescope, which uses adaptive optics to compensate for blurring effects introduced by viewing through the Earth's atmosphere. It reveals a pattern of atmospheric circulation parallel to the equator similar to the more familiar patterns on Jupiter and Saturn. There are also some bright, small storm systems.

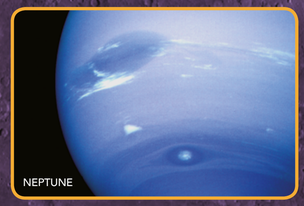
The mass of Uranus is about 14.4 times that of the Earth, whereas Neptune is about 17 Earth masses. We think that the middle of each is a rocky core with about the same mass as the whole Earth. Most of the rest is 'ice', surrounded by about one Earth-mass of gas, which is mostly hydrogen and helium. The interior 'ice' is under high pressure and is actually either liquid or at least sufficiently fluid to churn around and generate each planet's magnetic field. It is also certainly not pure water but must have plenty of ammonia and methane mixed in.

The continuous layer of clouds that forms the lowest level that we can see in each planet's atmosphere is made of tiny particles of frozen methane, in contrast to the ammonia clouds of Jupiter and Saturn. Seen through the gaseous methane above this cloud deck, it looks blue in visible light. Neptune's atmosphere in particular has some high-altitude clouds of methane ice, which look white because they are seen through less depth of gaseous methane. Above Neptune's clouds there is a tenuous haze of small hydrocarbon molecules such as ethane and ethyne, made by sunlight encouraging methane atoms to link together.

When Voyager 2 flew past Neptune in 1989 it saw several anticyclonic storms. The largest became known as the 'Great Dark Spot' by analogy with Jupiter's 'Great Red Spot'. There was also a 'Small Dark Spot' a little further 'south'. Both are in view in the image shown below. The Hubble Space Telescope noticed that both had vanished by 1994, so storms on Neptune seem to be less long-lived than their largest equivalent on Jupiter. But soon after this a similar storm appeared north of the equator, and became known as the 'Northern Great Dark Spot'.

Both planets have rings, with some tiny moonlets orbiting among them. They are much less spectacular than Saturn's rings, partly because they are made of much darker particles rather than the nearly pure water ice of Saturn's rings but also because they have much less mass. Uranus has 13 identified rings, which are made from particles ranging mostly between 20 cm and 20 m in size. Neptune has five rings, and these are much dustier than Uranus's rings. In both cases the rings are thought to be debris from one or more small moons that broke apart. They are probably relatively young features, no more than about 600 million years old.

Uranus has 27 known moons, of which the innermost 13 orbit within its ring system and help maintain the integrity of the individual rings. The equivalent numbers for Neptune are 14 and four. One of Uranus's outermost moons, a 20 km sized object named Margaret, has the most eccentric orbit of any known planetary moon, its distance varying between 4.9 million km and 23.8 million km.



Did You Know?

Uranus is a planet tipped over on its side. In 1986, when Voyager 2 flew past, its south pole was pointed toward the Sun so that its northern hemisphere was in darkness. By 2012, when the view shown above was captured, the planet was nearly side-on to the Sun.

THE MOON

The Moon is 384,000 km away. It rotates at the same rate that it orbits the Earth, so the same hemisphere of the Moon faces us all the time.

Our Moon is the sixth largest moon in the Solar System, with a diameter of 3474 km. Its surface gravity is one-sixth that of the Earth and it is home to some of the highest mountains and deepest basins in the Solar System with a difference in height exceeding 20 km. It has only a very thin atmosphere, called an exosphere, providing no protection from the Sun's radiation or impacts from meteoroids. As a result, its surface experiences temperature swings from +150 °C to -250 °C, and is covered by a layer of powdery dust and rocky debris called regolith.

The Moon formed about 4.5 billion years ago in the aftermath of a 'giant impact' between the early Earth and another planetary body. The newly formed Moon went through a 'magma ocean' phase, with less dense rocks floating upwards to form the lunar crust, visible today as the relatively bright lunar highlands.

In its first half-billion years, the Moon suffered heavy bombardment by impactors that produced large craters and basins (100–1000 km in diameter). Most basins on the near side were subsequently filled by basaltic lava flows that gave rise to smooth, dark features called 'maria' – Latin for 'seas'.

The Moon is the only object beyond Earth yet visited by humans. During the six Apollo missions between July 1969 and December 1972, 12 astronauts carried out field work, deployed scientific instruments on the lunar surface, and returned ~382 kg of rock and soil samples to Earth.

Our understanding of the formation and evolution of the Moon was revolutionised by analysis of returned lunar samples, leading to the acceptance of new ideas such as the 'giant impact' theory for the origin of the Moon and the 'lunar magma ocean'. Advances in laboratory instrumentation have recently enabled the detection of water in Moon rocks, necessitating re-evaluation of models describing the Moon's origin and evolution.

A renaissance in lunar exploration is heralded by the detection of water on the lunar surface by a number of recent spacecraft-based remote-sensing instruments. In particular, the presence of substantial deposits of water ice near the poles is considered important for addressing questions about the origin of life and for utilising local resources to support longer term Solar System exploration.

Did You Know?

The far side of the Moon (colloquially, but wrongly, called the 'dark side') is never visible from the Earth. The only spacecraft that has yet landed there is the Chinese *Chang'e-4*, which touched down with a rover called *Yutu-2* in January 2019.

OTHER MOONS

A moon is what we call any object orbiting a larger planetary body. The Moon, with a capital M, is the name of the moon that orbits the Earth.

Every planet apart from Mercury and Venus has moons. Mars has two small ones, which may be captured rocky asteroids. Jupiter has 79 known moons, of which four are bigger than our own Moon, and the other giant planets also have families of many moons. Currently 62 are known at Saturn, 27 at Uranus and 14 at Neptune but there are surely many small ones yet to be found.

Most of the giant planets' large moons probably grew from left-over material around each planet while it was forming, but their small outer moons are probably captured objects, and tiny moons in inner orbits are probably debris from larger moons that broke apart. Neptune's largest moon, Triton, is bigger than Pluto and was probably captured from the Kuiper Belt.

Almost every giant planet's moon consists mostly of ice, though the larger ones may have rocky cores. Those bigger than about 400 km in diameter have enough gravity to pull themselves into a spherical shape, but the smaller ones are irregular (such as Hyperion, 270 km moon of Saturn, seen on the left). The ice of Jupiter and Saturn's moons is mostly just frozen water, but further from the Sun the water ice is joined by ices made of frozen methane, ammonia, carbon monoxide and nitrogen.

Jupiter's innermost large moon, Io, is an exception. It is a rocky, volcanic world with eruptions going on all the time, powered by tidal heating.

Some icy moons are warm enough inside to have internal oceans sandwiched between ice above and rock below. It is thought that simple (microbial) life could exist there. NASA's Cassini spacecraft, which orbited Saturn, discovered a fine spray of frozen water droplets escaping from cracks in the icy shell of Saturn's 500 km moon Enceladus. It then flew through the plume to collect samples from the internal ocean.

Saturn's largest moon, Titan, is the only moon with a dense atmosphere – mostly nitrogen with about 5% methane. Here, liquid methane can fall as rain. It then flows across the icy surface and drains into large methane lakes.

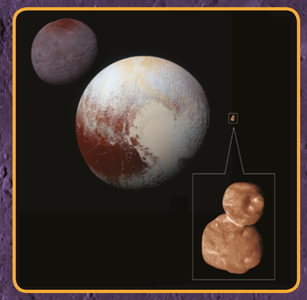
Rings surround each giant planet, inside the orbits of their large moons. Rings are not solid objects but are made of a multitude of fragments (some no more than dust, others metre-sized) too small to be tracked as individual moons.

Did You Know?

Asteroids can have moons too. For example, the 214 km wide asteroid Eugenia has two: 13 km Petit-Prince and an even smaller one informally named 'Princesse'. When the 325 m asteroid 2004 BL_{86} came close to Earth in 2015, radar studies showed that it has a moon only 70 m across.

THE KUIPER BELT

Kuiper Belt objects are icy worlds orbiting the Sun beyond Neptune's orbit, mostly between 30 and 70 times further from the Sun than the Earth is.



We didn't even know that the Kuiper Belt exists until the 1990s, when powerful telescopes began to detect numerous objects there. When it was discovered in 1930, Pluto was assumed to be a ninth planet, but now we realise that it is merely one of the nearer and larger of this new class of bodies. Thousands of Kuiper Belt objects have now been catalogued, and it is thought that there are probably more than 100,000 with diameters greater than 100 km.

The king of the Kuiper Belt is not Pluto but Eris, which has about 30% more mass than Pluto. Eris is denser than Pluto, so despite being the more massive of the two its diameter is fractionally smaller (about 2330 km diameter compared to Pluto's 2374 km). Eris has a moon, named Dysnomia, thought to be about 700 km in diameter, and 900 km Orcus has a moon named Vanth that is about 500 km across.

Since 2006, Pluto, Eris and two other of the largest Kuiper belt objects, Makemake and Haumea, have been officially classified as 'dwarf planets' on the grounds that their own gravity is strong enough to pull themselves into round shapes. Less massive Kuiper Belt objects are assumed to have irregular shapes.

Pluto and its largest moon, Charon (1212 km in diameter), seen here at their correct relative brightnesses, are the best known of the larger Kuiper Belt objects, having been seen at close quarters when the New Horizons space probe flew past in 2015. The bright region in the centre of Pluto's disc is nitrogen ice filling an ancient basin.

New Horizons flew past a more distant and smaller Kuiper Belt object catalogued as 2014 MU_{69} (nicknamed 'Ultima Thule') in January 2019 and showed that it consists of two icy lumps that collided at slow speed and stuck together to make a 33 km long 'contact binary', shown here enlarged relative to Pluto and Charon. This may be a clue as to how bodies merged to form the planets.

In 2018 astronomers using a telescope in Hawaii discovered the most distant known Kuiper Belt object, about 120 times further from the Sun than the Earth is. Catalogued as 2018 VG_{18} it is thought to be about 500 km in diameter.

Did You Know?

It is so cold in the Kuiper Belt that the bodies there are mostly ice – not just water but also methane, ammonia, carbon dioxide and nitrogen. The larger ones may have rocky cores. Many are very dark and red, possibly because radiation has converted methane into long chains of tarry organic molecules.